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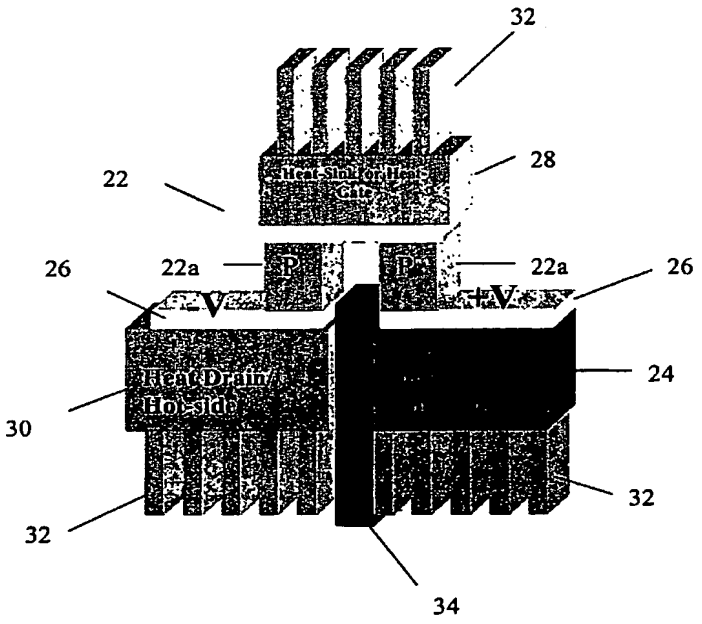
(54) Title: TRANS-THERMOELECTRIC DEVICE



(57) Abstract: A thermoelectric device having at least one unipolar couple element (22) including two legs (22a) of a same electrical conductivity type. A first-temperature stage (24) is connected to one of the two legs. A second-temperature stage (28) is connected across the legs of the at least one unipolar couple element. A third-temperature stage (30) is connected to the other of the two legs. Methods for cooling an object and for thermoelectric power conversion utilize the at least one unipolar couple element to respectively cool an object and produce electrical power.

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

comprises:

a p-p couple with each leg of said two legs having at least one of a different material composition and a different structure from the other leg.

27. The device of Claim 26, wherein the p-p couple comprises:

a p-type $Bi_{1.0}Sb_{1.0}Te_3$ thermoelement; and

a p-type $Bi_{0.5}Sb_{1.5}Te_3$ thermoelement.

28. The device of Claim 26, wherein the p-p couple comprises:

a p-type 10 Angstrom/30 Angstrom Bi_2Te_3/Sb_2Te_3 superlattice thermoelement; and

a p-type 10 Angstrom/50 Angstrom Bi_2Te_3/Sb_2Te_3 superlattice thermoelement.

29. The device of Claim 1, wherein the at least one unipolar couple element comprises:

a n-n couple with each leg of said two legs having at least one of a different material composition and a different structure from the other leg.

30. The device of Claim 29, wherein the n-n couple comprises:

an n-type $Bi_2Te_{2.5}Se_{0.5}$ thermoelement; and

an n-type $Bi_2Te_{2.85}Se_{0.15}$ thermoelement.

31. The device of Claim 29, wherein the n-n couple comprises:

an n-type 10 Angstrom/30 Angstrom $Bi_2Te_3/Bi_2Te_{2.85}Se_{0.15}$ superlattice thermoelement; and

an n-type 10 Angstrom/50 Angstrom $Bi_2Te_3/Bi_2Te_{2.85}Se_{0.15}$ superlattice thermoelement.

32. A thermoelectric device comprising:

at least one unipolar couple element having two legs of a same conductivity type;

an intermediate-temperature stage connected between said legs of the at least one unipolar couple element on a common side of the unipolar couple element; and

electrical contacts to each leg of the unipolar couple element such that current flows in opposite directions in adjacent legs of the unipolar couple elements.

33. The device of Claim 32, wherein said at least one unipolar couple element is configured such that current flows in opposite directions in the legs of the at least one unipolar couple element to establish a temperature differential across the two legs of said unipolar couple element.

34. The device of Claim 32, wherein said at least one unipolar couple element is configured to generate at least one of an electrical potential and an electrical current from a temperature differential established across the two legs of said unipolar couple element.

35. The device of Claim 32, wherein the at least one unipolar couple element comprises:

a p-p couple with each leg of said two legs having at least one of a different material composition and a different structure from the other leg.

36. The device of Claim 32, wherein the at least one unipolar couple element comprises:

a n-n couple with each leg of said two legs having at least one of a different material composition and a different structure from the other leg.

37. A thermoelectric device comprising:

at least a four-temperature-terminal device including,

a p-p unipolar couple element having legs of a p-type electrical conductivity,

a first intermediate temperature stage connected across said legs of the p-p unipolar couple element,

a n-n unipolar couple element having legs of an n-type electrical conductivity, and

a second intermediate temperature stage connected across said legs of the n-n unipolar couple element and operated at a temperature different than first intermediate temperature stage.

38. The device of Claim 37, further comprising:

electrical contacts connecting to each of said legs of the p-p and said legs of the n-n unipolar couple elements, said electrical contacts are connected such that currents flow in opposite directions in each of the legs of the p-p unipolar couple element and in each of the legs of the n-n unipolar couple element to establish a temperature differential across each of the p-p unipolar couple element and the n-n unipolar couple element.

39. The device of Claim 37, wherein said p-p unipolar couple element and said n-n unipolar couple element are configured to generate at least one of an electrical potential and an electrical current from a temperature differential established across said p-p unipolar couple element and said n-n unipolar couple element.

40. A thermoelectric device comprising:

a heat source;

means for generating currents flowing in opposite directions in two legs of a thermoelectric material of a same conductivity type, said means coupled to said heat source;

an intermediate-temperature stage connecting to a common side of the legs of the thermoelectric material toward the heat source; and

a heat sink coupled to said two legs and configured to dispose heat from said thermoelectric device.

41. The device of Claim 40, further comprising:

an intermediate-temperature stage connected across said two legs; and

a temperature controller configured to control a temperature of the intermediate-temperature stage.

42. The device of Claim 40, wherein said means for generating currents comprise:

a metal contact interposed between and connecting to said two legs;

two electrical contacts connected to respective ends of said two legs opposite said metal contact; and

a voltage applicator configured to apply an opposite voltage potential to respective of said electrical contacts.

43. The device of Claim 40, wherein said means for generating currents are configured to provide said currents to establish a temperature differential across the two legs.

44. The device of Claim 40, wherein said means for generating currents are configured to generate, from a temperature differential across said two legs, at least one of an electrical potential and an electrical current.

45. The device of Claim 40, wherein said means for generating currents comprise:

a p-p couple with each leg of said two legs having at least one of a different material composition and a different structure from the other leg.

46. The device of Claim 40, wherein said means for generating currents comprise:

a n-n couple with each leg of said two legs having at least one of a different material composition and a different structure from the other leg.

47. A method for cooling an object, comprising:

conducting heat from the object to a thermoelectric device including a unipolar couple element having two legs of a thermoelectric material of a same conductivity type; and

flowing currents in opposite directions in said two legs to transport said heat across each of said legs in a direction away from said object; and

disposing of said heat from the thermoelectric device through a heat sink into an ambient environment.

48. The method of Claim 47, further comprising:

controlling a temperature of an intermediate-temperature stage connected between said legs.

49. The method of Claim 47, wherein said flowing currents comprises:

applying opposite voltage potentials to respective of two electrical contacts at ends of said two legs.

50. The method of Claim 47, wherein said flowing currents establishes a temperature differential across the two legs to cool said object.

51. A method for thermoelectric power conversion, comprising:

extracting heat from a heat source coupled to a thermoelectric device including a unipolar couple element having two legs of a thermoelectric material of a same conductivity type; and

maintaining a temperature differential across the thermoelectric device to a heat sink to produce electrical power from the thermoelectric device; and

dissipating heat from said heat sink into an ambient environment.

52. The method of Claim 51, further comprising:

controlling a temperature of an intermediate-temperature stage connected between said legs to produce electrical power.

53. The method of Claim 51, further comprising

controlling a temperature of an intermediate stage by introducing a fluid exiting from a hot-stage coupled to the heat source onto the intermediate stage.

54. The method of Claim 53, wherein said controlling a temperature mixes said fluid

exiting from a hot-stage with a lower-temperature fluid.

55. The method of Claim 51, wherein said maintaining a temperature differential generates at least one of an electrical potential and an electrical current from the thermoelectric device.

tem of imaging elements.

INTERNATIONAL SEARCH REPORT

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A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : H01L 35/04, 35/18, 35/32, 35/34
US CL : 136/201, 203, 205, 211, 212, 240

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 136/201, 203, 205, 211, 212, 240

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X,P --- A,P	US 2003/0209014 A1 (CHANG et al) 13 November 2003 (13.11.2003), Figure 3, and paragraph 0008.	32-36, 40-55 --- 1-31, 37-39,
Y	JP 2002-111080 A (OKADA) 12 April 2002 (12.04.2002), Figure 1.	1-55
Y	JP 2002-232028 A (ONOE et al) 16 August 2002 (16.08.2002), Figures 1, 4, and 5.	1-55
A	US 3,615,870 A (CROUTHAMEL) 26 October 1971 (26.10.1971).	1-55
A	US 2002/0046762 A1 (ROSSI) 25 April 2002 (25.04.2002).	1-55

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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